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AVIATOR PSYCHOLOGICAL AND PHYSIOLOGICAL RESPONSES TO REPLACEMENT AIR GROUP TRAINING*

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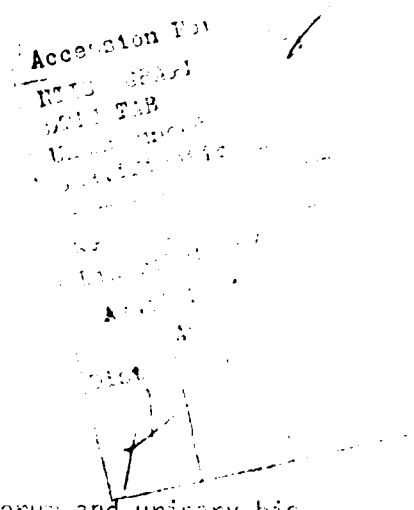

ABSTRACT

Performance, perceived stress, psychological moods, and serum and urinary biochemical measures were analyzed in a sample of naval aviators undergoing replacement air group training in the F-4 aircraft. The aviators, as a group, rated the first F-4 flight as the most stressful training flight and concomitantly showed significant increases in serum lactic acid, pyruvic acid, urinary norepinephrine and urinary creatinine during this flight. Pilots throughout training obtained significantly higher performance scores and showed significantly less fear and fatigue than did radar intercept officers (RIOs). Pilots' perceived stress and performance scores were unrelated. RIOs' radar trainer stress scores were significantly correlated with performance during their subsequent radar flights.

Indexing: Aviators Training Stress Catecholamines

INTRODUCTION

Combat readiness frequently involves demanding training, with attendant arousal of psychological and neuroendocrine systems (11). It has been a goal of researchers studying stress in the military to utilize subjective reports of mental stress, as well as physiological responses to these stresses, to estimate the medical consequences of these stressful training programs (6,7,8,9,11,16). Evaluations of the trainees' profiles of physiological reactivity to training stresses have shown some promise as predictors of performance during training (6,7,8,9,11,12).

Replacement Air Group (RAG) training programs for Navy aviators consist of phases involving both simulated and actual flights. RAG training entails tactical flying and weapons deployment in a progressive program where the men have time to prepare for each new training challenge. Research carried out in RAG training with F-4 jet aircraft squadrons offered the unusual opportunity to study differences in perceived stress and physiological arousal between pilots and radar intercept officers (RIOs). While pilots have direct flight control, RIOs operate all electronic equipment and specify the course and maneuvers necessary to accomplish a mission.

In the present study it was hypothesized that during specific phases of RAG training, pilots and RIOs would perceive different levels of stress depending upon the extent to which the training applied to their specific job demands. It was also hypothesized that blood and urinary biochemical responses would correspond to levels of perceived stress. Lastly, it was hypothesized that performance would be related to aviators' perceived levels of stress.

METHODS

Subjects

One F-4 RAG squadron, consisting of 13 trainee pilots (mean age 25.6 years) and 11 trainee RIOs (mean age 24.8 years) participated in the study. All men had completed a college education and the majority in each group were unmarried. All were Caucasian males who were provided voluntary consent and protection of human subjects information.

Training Program

The RAG syllabus for F-4 jet aircraft at the Miramar Naval Air Station, San Diego, California, is divided into several phases. A control day, along with the first days of simulated or actual flight in three of these training phases, were selected for study. The control day was the day prior to the beginning of RAG training. The first phase of training, familiarization and instrumentation (FAM), includes computer simulation of different aspects of F-4 flight operations, as well as actual flights. The first simulator experience (FAM Trainer) was the second study day, and the first actual flight in the F-4 was the third study day. The radar phase involves the introduction to the radar system and an all-weather weapons system with emphasis on basic intercept techniques. The first computer simulated flight in this phase (Radar Trainer) was the fourth day studied and the first actual radar weapons flight (Radar Flight) was the fifth study day. The sixth and final study day was the initial aircraft mission where conventional weapons (Bombing) was carried out. Whereas pilots had the primary responsibilities during the FAM trainer and FAM flight, RIOs had primary responsibilities during the Radar trainer and Radar flight.

Performance Scores

The men were evaluated for their performance on every simulated and actual flight. There were different instructors present during each flight, as well as during the training phases; therefore, average performance scores for the actual flights of a training phase studied (FAM, Radar, and Bombing) were computed to reduce between-instructor differences in scores.

Biochemical Measurements

Six blood samples and five urine specimens were collected on each participant. These samples were taken on the control day (blood only) and on each of the five training days studied. Blood samples were collected just prior to each simulated or real flight. Immediately after venipuncture, a 2 ml aliquot of whole blood was precipitated with cold 0.5 N perchloric acid and frozen for subsequent analyses for lactic and pyruvic acid. The remainder of the blood sample was centrifuged and the serum recovered and frozen for later analyses for serum cholesterol and uric acid. Cholesterol was determined by the method of Clark, et al., and uric acid by the enzymatic method of Liddle, et al. (1,4). Lactic acid was determined by the Rapid Lactate Method (Rapid Lactate Fast Pack, patented by Calbiochem, 10933 Torrey Pines Road, La Jolla, CA 92037). Pyruvic acid was determined by the enzymatic method of Marbach, et al. (5).

Timed urine samples were collected at the end of each of these flights. The subjects voided prior to and once again within 15 minutes after the flight. The average duration of urine collection was 180 minutes. These timed specimens were measured for volume before 10 ml aliquots were frozen for later analyses for catecholamines. Urinary catecholamines were determined by a modification of the technique developed by Von Euler and Lishajko with the urine samples acidified to ph 3.0 with concentrated HCL (14). Urinary creatinine was measured by the method of Henry (3).

Life Change Scoring

The Recent Life Changes Questionnaire (RLCQ) was administered on the control day and again on each study day. The first administration of the RLCQ queried subjects regarding the occurrence of 42 life events over the past two years--divided into four, six-month intervals: 0-6 months, 7-12 months, 13-18 months, and 19-24 months ago (10). For the next five administrations, subjects were asked which life events had occurred during the interval since last completing the questionnaire. Two methods of scoring the RLCQ were used: 1) the number of events having occurred; 2) the sum of the Life Change Units (LCU) for the events having occurred. These two scores were computed for the four time periods on the initial RLCQ and for each of five interval measures.

Mood Questionnaire

The Mood Questionnaire (MQ) was also administered on the control day and at the time of each blood draw. The MQ consists of 40 adjectives describing a person's current psychological mood (13). The individual response to each of the adjectives was: 1=not at all, 2=somewhat or slightly, 3=mostly or generally. The MQ has six scales: Happiness, Activity, Depression, Fear, Anger, and Fatigue. Each scale has from five to seven adjectives and was scored by summing the various responses to the adjectives in the scale.

Perceived Stress Measure

Following completion of the RAG syllabus, each trainee provided a retrospective evaluation of his perceived stress on the control day and on each training day studied. The rating scale ranged from 0 (no stress) to 10 (maximum stress). The first radar flight was inadvertently omitted from the rating form and consequently no stress measure was obtained for this study day.

Statistical Analyses

Stress, mood, biochemical, and performance variables were analyzed by groups (pilots vs. RIOs), and by time period (days of training studied) using a two-way analysis of variance for repeated measures (ANOVA). Analyses of the time period differences are based on the combined pilot and RIO time period data. The Geisser-Greenhouse (15) method of degrees of freedom adjustment was used as a conservative estimate of significance in differences of means (the F). Tukey's Honestly Significant Difference Test was computed for all variables which showed a significant effect over time to indicate which time period means were significantly different (15).

To test the hypothesis about the relationship between performance and perceived stress, Pearson product moment correlations were computed for pilots and RIOs separately. Since Pearson correlations can be inflated due to the extreme variation in small samples such as these, Spearman rank order correlations were computed to verify each significant Pearson correlation.

RESULTS

Training Stress

Results of the two-way ANOVA of the trainees' stress ratings are presented in Table I. No significant group differences were seen between pilots and RIOs, and no significant interaction of time and groups was observed. Perceived stress was significantly different, however, between days of training (time periods) for the total aviator sample ($p<0.001$). Aviators' overall stress ratings were lowest at the start of training and highest for the first F-4 flight. Pilots, as a group, rated the first F-4 flight as the most stressful of all flights studied. Although not statistically significant, RIOs rated the first radar trainer as the most stressful training day studied.

[Insert Table I about here]

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[Insert Table II about here]

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ed during the radar trainer. Though not statistically significant,
catecholamines were at their highest levels at their first radar
e results are shown in Table III.

[Insert Table III about here]

[Insert Table I about here]

Performance Measures

Mean performance scores over all days sampled ranged from 2.95 to 3.42 on a four-point scale (Table II). For both pilots and RIOs, a trend was seen for initial high scores to be followed by a decline, with a stabilization of scores over the final two flights. This trend was not statistically significant, however. Pilots received significantly ($p<0.01$) higher marks, as a group, than did RIOs.

[Insert Table II about here]

Biochemical Measures

All biochemical measures were seen to remain within normal limits across all study days. There were no significant differences between pilots and RIOs, and none of the groups x time interactions were significant. Serum lactic acid, serum pyruvic acid, urinary creatinine and urinary norepinephrine varied significantly by days, with the highest values seen at the first F-4 flight and lowest values observed during the radar trainer. Though not statistically significant, RIOs' urinary catecholamines were at their highest levels at their first radar flight. These results are shown in Table III.

[Insert Table III about here]

There were two training phases (RAG and Radar) in which pilots and RIOs (Trainee) experience was followed by actual flights. This was done to compare the biochemical responses between the simulator and actual flight. No significant differences in the scores determining both simulator and flight were observed. Further, pilots showed no significant differences in their urinary measures between the simulator and actual flights. RIOs, however, showed significantly higher urinary norepinephrine ($p<0.01$) during the radar flight compared to the radar trainer experience.

Mood Scales

Pilots had significantly ($p<.01$) lower means than RIOs for the mood scales Fear and Fatigue. Fatigue also varied significantly ($p<.05$) over time, with the lowest mean prior to the first F-4 flight and the highest on the control day (this pattern was found for both pilots and RIOs). There were no significant differences between pilots and RIOs or across the training sessions studied for the other four mood scales (Depression, Anger, Activity and Happiness).

Life Changes

Pilots reported significantly fewer life change units (LCU) and total recent events than the RIOs during the 0-6 months time interval immediately prior to RAG training ($p<.05$). The intervals between administrations proved to be too short for meaningful accumulations of life changes for either group. Correlations between 0-6 months life change units, performance marks, perceived stress and the biochemical variables resulted in no significant relationships.

Performance and Stress

Intercorrelations computed between perceived stress scores and performance evaluations indicated only one significant relationship. In the RIO sample, stress

rating for the radar trainer and the overall evaluation score for the radar trainer phase correlated (r=.88 (p<.05).

DISCUSSION

This study investigated psychological stress, moods, physiology, and flight performance in naval pilots and RIOs in F-4 Replacement Air Group training. By and large, the results indicated that regardless of the challenges and risks involved, all psychological and physiological assessments were within normal limits. Pilots and RIOs, as a group, rated the F-4 flight as the most stressful point in training. Since the stress rating for the first radar flight was inadvertently omitted, it is of interest to project how this point in training might have been seen by both pilots and RIOs. For example, it was observed that RIOs rated the radar trainer to be more stressful than the F-4 flight. It could be expected, then, that the first radar flight would have been rated even higher by RIOs. RIOs did show peak urinary catecholamine excretion during this first radar flight. Due, in part, to this methodological error, Hypothesis 1 was not confirmed--that perceived stress would vary depending on the different job demands for pilots and RIOs.

Several biochemical measures varied significantly over the course of training. Serum lactic acid, pyruvic acid, urinary norepinephrine and creatinine were significantly elevated, for all aviators, for the first F-4 flight. This was also the point of highest perceived stress (Hypothesis 2). Urinary catecholamines for all aviators correlated (r=.54, p<.05) with serum lactic acid on the day of the F-4 flight, although this was not confirmed by Spearman rank order correlation. Both serum lactic acid and lactate/pyruvate ratio have been linked to subjects'

response to stress (9). Possible mediators include hyperventilation, anxiety, anticipation, and overall cardiac output. Catecholamine excretion may partially explain the observed serum lactate elevation. Urinary creatinine has been seen previously to be elevated during stress situations (13). The lack of any specificity of biochemical responses by pilots versus RIOs is surprising. A suggestion of training-specific physiological responses was seen in pilots' versus RIOs' urinary catecholamines data (Table III).

Serum uric acid levels tended to be higher for pilots than RIOs, and tended to be relatively elevated for both groups early in training. These trends, though not statistically significant, parallel previous findings from this laboratory (6,9,12). Elevated levels of serum uric acid were also observed in these previous studies to mark those individuals who were highly successful in training. Thus, the relatively higher serum uric acid levels seen for pilots versus RIOs is in the expected direction, given their higher performance scores.

For pilots, the F-4 flight phase was their transition into a full-size fighter aircraft following a series of comprehensive sessions in a simulator. The F-4 aircraft does not have dual controls, thus the instructor can only provide verbal guidance. It was observed that pilots' urinary epinephrine excretion during the simulator flights for both the FAM and Radar phase significantly correlated with their average performance for each of these phases. The trainer epinephrine value-to-average performance correlation was 0.74 ($p<.01$) for the FAM phase and 0.70 ($p<.05$) for the Radar phase. This suggests that the pilots who responsed to the simulator experiences with an activation of epinephrine release, performed better during the period of actual flights to follow. Such relationships between

catecholamine [illegible] and performance have been demonstrated by Frankenhaeuser, et al., in less challenging and far safer settings (9).

Similarly, during the radar phase, RIOs assumed full responsibility for navigation, communication, and radar controls for the first time in actual flight conditions. RIOs' performance during the radar flight was not related to their catecholamine excretion, but during subsequent radar flights a significant negative correlation was seen between performance and perceived stress scores for the radar trainer. This finding suggests that high perceived stress levels in RIOs subsequently interfered with their radar flights' performance (Hypotnesis 3).

There was some evidence that human physiological and psychological responses vary with the level of training stress. The ratings of perceived stress were retrospectively collected, and a stronger relationship between the stress ratings and the performance scores might have been observed with daily stress ratings. The daily ratings might be less effected by memory and perceptual distortion, and influences outside the training setting. Further work relating individual differences in perceived stress to differences in reactivity is suggested.

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TABLE I

Aviators' Retrospective Stress Ratings During RAG Training

Time Periods Sampled

Group	N	Control	First FAM Trainer	First F-4 Flight	First Radar Trainer	First Bombing Flight
Pilots $\bar{X}$	13	3.15	4.69	7.15	3.77	3.62
SD		3.53	2.59	2.94	2.49	1.85
RIO's $\bar{X}$	11	1.73	4.64	4.82	5.00	3.60
SD		1.74	2.42	2.93	3.32	2.01
Total Means	24	2.50	4.67	6.08	4.33	3.61

F(groups) = .2; ns

F(time) = 7.8; p<.001

F(groups x time) = 2.3; ns

TABLE II

Mean Performance in Miramar Aviator F-4 RAG Training

	RAG Training Phases				
Group	First FAM Trainer	First F-4 Flight	First Radar Trainer	First Radar Flight	First Bombing Flight
Pilots	3.42	3.30	3.08	3.20	3.20
SD	.47	.22	.11	.13	.21
RIO's	3.28	3.09	2.98	3.10	3.10
SD	.58	.10	.18	.18	.17

F(groups) = 5.1; $p<.01$

F(time) = 3.7, ns

F(group x time) = .4; ns

TABLE III

Mean Values of Biochemical Variables During RAG Training

		Control	First FAM Trainer	First F-4 Flight	First Radar Trainer	First Radar Flight	First Bombing Flight	ANOVA Tukey's HSD	ANOVA Between Groups	ANOVA Over Time	ANOVA Interaction
SERUM:											
Cholesterol (mg/100 ml)	Pilot	205	203	210	199	208	197	–	.1	1.8	.9
	RIO	200	208	211	207	206	209				
Uric Acid (mg/100 ml)	Pilot	6.4	6.3	6.2	6.2	6.1	6.0	–	1.9	1.3	.4
	RIO	5.7	6.0	6.1	5.5	5.6	5.7				
Lactic Acid (mg/100 ml)	Pilot	14.9	14.5	16.7	11.9	15.1	11.1	5.9	.5	4.7*	.8
	RIO	15.2	20.0	21.1	10.9	14.6	12.8				
Pyruvic Acid (mg/100 ml)	Pilot	.52	.60	.77	.48	.52	.47	.19	3.7	9.6*	.2
	RIO	.57	.75	.88	.50	.61	.54				
URINARY:											
Norepinephrine (ng/ml)	Pilot		7.8	12.5	4.9	6.6	10.5	2.7	2.1	10.8**	2.9
	RIO		4.7	8.7	3.9	9.0	7.7				
Epinephrine (ng/ml)	Pilot		5.0	5.6	2.7	4.4	6.3	–	.5	4.0	2.7
	RIO		5.6	5.6	4.3	7.8	5.1				
Creatinine (ng/ml)	Pilot		227	304	157	190	258	60.7	2.6	5.9*	2.9
	RIO		171	214	150	216	185				

*$p < .05$

**$p < .01$

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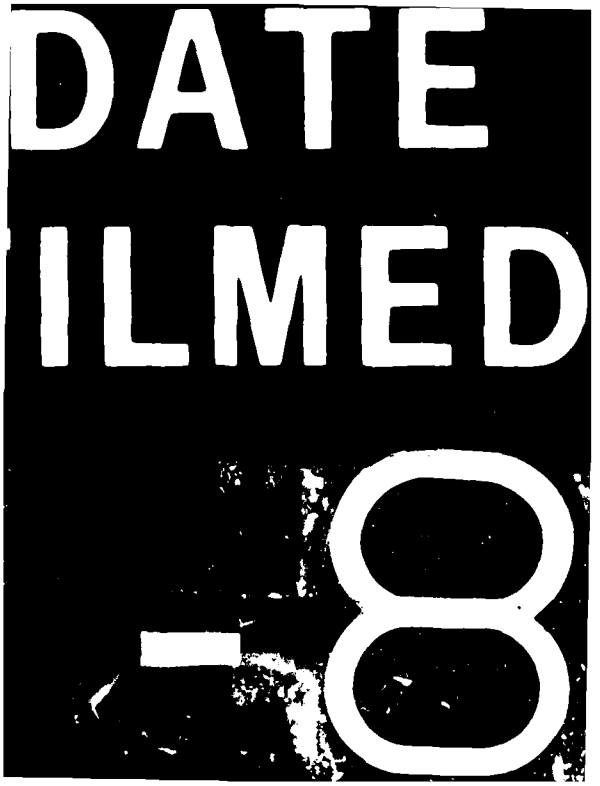
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